Communications System Architecture Development

for

Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.12, Identify Communications Components, Systems and Technologies for Research & Development

(Task 11.0)

Prepared By

ARINC
Science Applications International Corporation (SAIC)
TRW

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1. Introduction

1.1. Overview

This document presents the candidate technology solutions to fill the communications system and technology gaps identified in Task 10. This information is useful for future technology development and planning purposes.

1.2. Terms and Definitions

The following terms and definitions provide the framework for identifying and categorizing the gaps (Task 10) and candidate solutions (Task 11).

1.1.1 System Gaps

System gaps are concerned with the collection, processing, and distribution of information necessary for safe and efficient operations within the NAS. System gaps fall under one of the following categories defined below:

- New systems: An entirely new method of collecting, processing, and distributing data is required to meet the new requirements of the proposed 2015 Communications System Architecture.
- New or improved data link: The protocols and hardware necessary to distribute data through the network are inadequate for the expanded requirements and need improvement.
- Improved network: The protocols are adequate for the expanded requirements; however, the physical configuration (number and location of network nodes) can be improved to provide improved access, response time, and availability.

1.1.2 Component Technology Gaps

Component gaps are specified at the following level (applicable to air, ground, and space platforms):

- Radio Frequency (RF) Technology (receivers, transmitters, RF converters, etc.): The hardware that enables wireless transmissions between nodes in such a manner that it may be transmitted and received via antenna technology.
- Antenna Technology: The hardware by which a node in the network receives and transmits RF signals.
- Network/switching and routing technology: The software used to connect the various network nodes and ensure that information is properly routed to the correct destination.

1.3. Relationship to Other Tasks

Task 11 is based on the summary and conclusions drawn from the recommended AATT and AWIN Communications System Architectures (CSA). The purpose of the document is to present candidate solutions to the technological gaps identified in Task 10. Figure 1.3-1 shows the relationship of Task 11 to the other Advanced Air Transportation Technologies (AATT) TO24 Tasks.

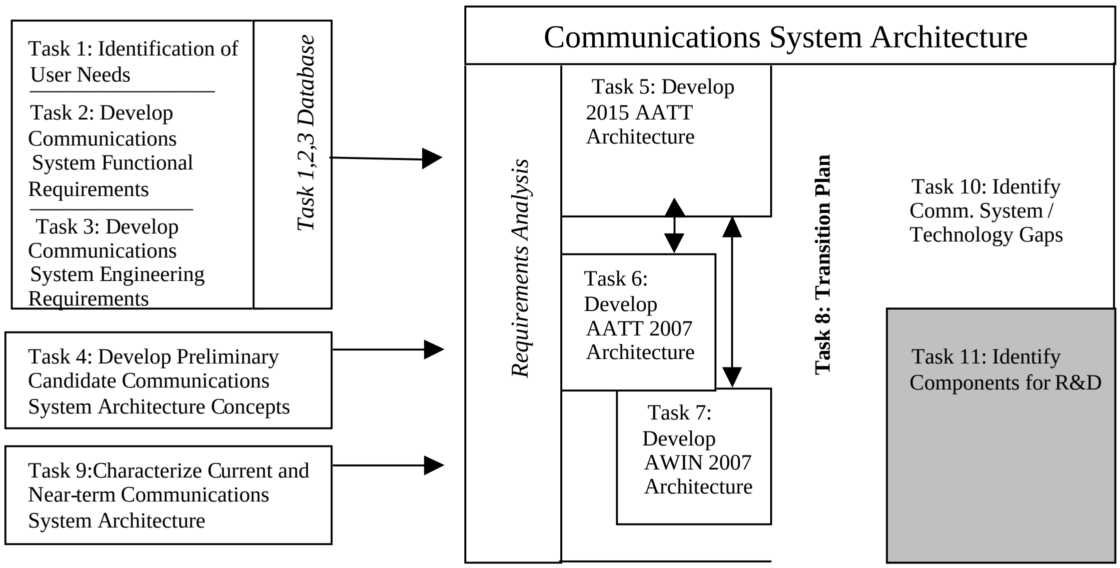

Figure 1.3-1. Relationship of Tasks

1.4. Summary Of Communications System and Technology Gaps

The shaded areas in Figure 1.4-1 below represent the communications system technology gap areas addressed in the Task 10 Report. The ground segment gaps include the interface to the NAS-Wide Information System (NWIS) and to commercial passenger services. It is believed that this is the area where standards for data, security and inter-network (ATN/Non-ATN) communications need further definition. In addition, the interface between commercial service providers and the FAA systems will require selection of numerous communications related standards and performance metrics. In the air segment (shown on the right of the chart) the avionics must support multiple communications links, high-speed data rates, and communications between various data communications processors and displays. In the space segment (indicated by the satellite icon), it is assumed that commercial service providers will have the satellites in place by 2007 to offer broadcast services to airspace users via Ka-band. The gap is in the availability of suitable antennas and receivers for all classes of aircraft that resolve the problems associated with rain attenuation, weight, flexibility and end-user cost.

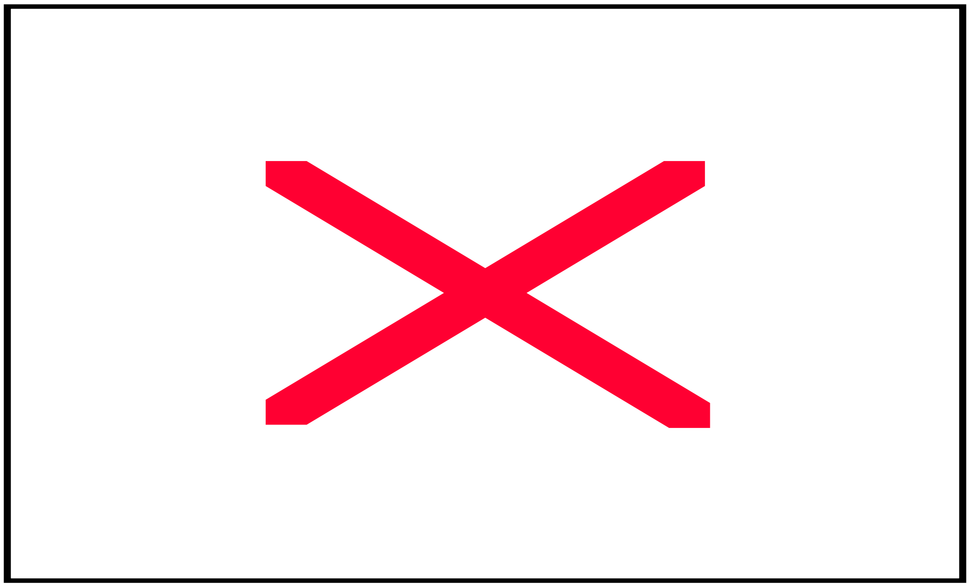

Figure 1.4-1. Communications Technology Gaps

An analysis of the recommended architecture revealed a number of gaps related to communications systems and components, which are summarized below. The potential solutions may include systems and components that are readily available (commercial off-the-shelf) as well as new systems and components that must be developed or adapted for use in the aeronautical environment. Task 10 focused on details related to the gaps. Task 11 focuses on the potential solutions and areas that require further research and development. It is with some reservation that we use the term "research" and offer the following qualifier:

> The communications technology discussed in this section is already in various stages of development or is commercially available with few exceptions. However, work must be done in all cases to adapt the technology to the various classes of aircraft and ensure that it meets the certification requirements imposed by the FAA at the appropriate level.

1.2 Summary of Gaps by Segment

The table below lists the gaps by ground, air and space segment and indicates whether the gap is a system or component level gap.

Table 1.2-1. Communications Technology Gaps by Segment

Architecture Requirement	*Communications Technology Gap Areas*	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	**Advanced Aircraft Information System**	New System Required			
	High Speed Network (Flight Deck/Cabin)	Improved Component		x	
	Server	Improved Component		x	
	Multifunctional Displays	Improved Component		x	
	Intelligent Router	Improved Component		x	
2007	**VHF Improvements**				
	Directional VHF Antennas	Improved Component		x	
	Modulation	Improved System	x		
	Virtual Network	Improved System	x		
	Compression	Improved Technology	x		
	Voice synthesis	Data Link	x		
2007	**SATCOM**	New System, Component and Datalink Required			
	Multi-mode Radio with Ka-band Interface	Improved Component		x	
	Development of efficient modulation techniques for Ka satellite bands	Improved Component		x	x
	Mobile Standards	Improved System			x
	Ka-band Receiver Improvements	Improved Component		x	
	Ka-band Antenna Improvements	Improved Component		x	
2015	**Traffic Information System**	New System Required			
	Com. Interface to TIS (standard data set, access protocol, user verification)	New System	x	x	

Table 1.2-2. Cross-Cutting Technology Issues

Architecture Requirement	*Cross-Cutting Technology Issues*	System or Component	Segment		
2007/2015			Ground	Air	Space
2015	**NAS-Wide Information System**	New System Required			
	Com. Interface to Distributed NAS Wide Database (standard data set, access protocol, user verification)	New System	x	x	
2007	**Information Security**	Improved Datalink Required			
	Authentication	New System	x	x	
	Data Validation	Improved System	x	x	
	Protection from Interference	Improved System	x	x	x

2 Communications Solution Alternatives for Research & Development

2.1 Communications Technology Gap Areas

The Free Flight and Distributed Air/Ground Traffic Management, (DAG-TM) concepts are predicated on a common situational awareness among the air traffic controller, the pilot, and service providers such as air carrier dispatchers. Based on this common view of the situation, all users can negotiate on traffic management problems (such as hazardous weather, airport closures, equipment failures), and can exchange information such as observed weather, flight plan modifications, and deviations. The amount of data required to support the Free Flight and DAG concepts including graphical FIS and TIS products is expected to greatly increase the demands on the aircraft communications system and VHF spectrum. The following sections discuss the need for an Advanced Aircraft Information Systems (AAIS), VHF improvements and a satellite data link to accommodate future air/ground data distribution.

2.1.1 Advanced Aircraft Information System

With more data being sent to the cockpit, an aircraft network similar to ground local area networks will be needed. Higher data rates, increasing exchanges between on-board processors, and the combined need for high reliability and ease of installation drive the need for an aircraft network.

This section focuses on the need for development of the Advanced Aircraft Information System (AAIS) consisting of a high speed network (Flight Deck/Cabin), aircraft server, multifunctional displays, and intelligent router. This is considered a communications technology system gap because it is not addressed in the current NAS plan but is an integral part of the recommended AATT 2015 Architecture as well as the 2007 AATT and AWIN Architectures.

2.1.1.1 High Speed Network

This section discusses the need for an aircraft network similar to terrestrial LAN designs but suitable for aircraft environments. The current aircraft network is described for comparison.

Present aircraft flight deck communications are supported by a variety of audio and data link transceivers that operate in the Very High Frequency (VHF), High Frequency (HF), and Satellite Communications (SATCOM) (L-band) frequency. Historical functionality requirements placed the analog audio and the data link in the same units to minimize the number of on-board radios. Each radio is capable of either voice or data but typically is switched to only one mode. Figure 2.1-1 shows the configuration of current multiple radio installations for air carriers (Class 3 and 2). The wiring from the antenna to the Communications Management Unit (CMU) is independent for each radio. Radios are considered critical for flight operations and commercial airplanes have dual and triple redundancy.

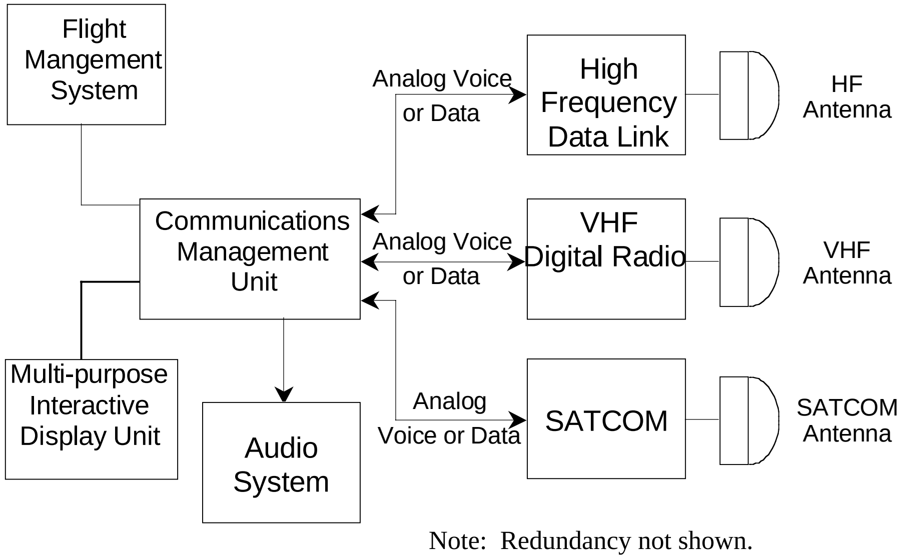

Figure 2.1-1. Present Configuration of Aircraft Communication Systems

In addition to distribution of information among on-board equipment, future aircraft cabin services such as In-Flight Entertainment (IFE), e-commerce, and Internet applications will require a flow of information to and from aircraft that will approach 10 Mbps during flight. Distribution within the aircraft will require a high speed bus or local area network (LAN). Existing terrestrial LANs achieve 100 Mbps, which would provide sufficient performance and growth potential for the proposed aircraft environment.

Aircraft networks will have additional requirements beyond those of terrestrial LANs. Aircraft installations require FAA certification including consideration of EMI, fire safety, redundancy, failure modes, security and maintenance. If the network carries ATC, AOC and passenger traffic, it will require information security, quality of service provisions and a priority scheme. Adaptation of existing commercial LANs will need to address these requirements.

Current technologies such as Fiber Distributed Data Interface (FDDI), are potentially applicable to the aircraft network requirements. FDDI is designed to handle synchronous data for voice and video, provides high capacity, is immune to EMI, has redundancy features, and is lightweight.

As previously stated, existing radios are operated in either a voice or data mode. In contrast, the future aircraft communications system will carry both voice and data over the same wiring as shown in Figure 2.1-2, Notional Block Diagram for 2015 Aeronautical Communication System (ACS) Integrating Data and Digitized Voice).

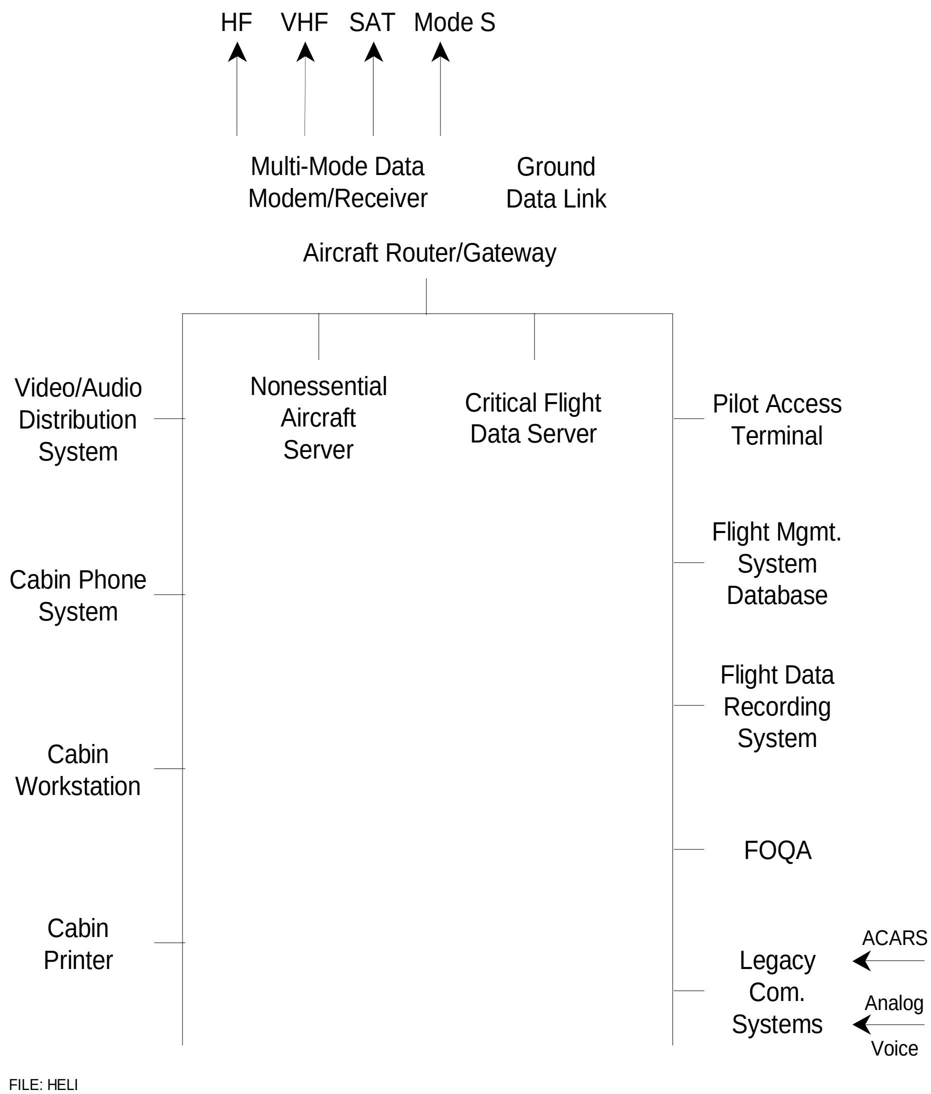

Figure 2.1-2. Notional Block Diagram for 2015 Aeronautical Communication System (ACS) Integrating Data and Digitized Voice

2.1.1.2 Aircraft Servers

In 2015, each aircraft will access the NAS-Wide Information System (NWIS) to determine the impact of changes on the flight. Information regarding current and predicted weather, traffic density, restrictions, and status of Special Use Airspace (SUA) will be available, through NWIS to all aviation service providers and airplane crews. The communications interface has not yet been determined.

The network architecture will require an aircraft server that takes advantage of shared media and can route all NWIS information. The architecture, operating system, major applications, and the NAS-wide database management needs of that server must be defined. Further, the server must be integrated into distributed architectures to support priority of critical traffic and meet availability and other performance criteria.

2.1.1.3 Multifunctional Displays

The volume of new information available to the pilot will require an effective means of presentation. Most studies and efforts have assumed a multifunction display will be used to present a wide variety of text and graphics. Suitable displays that are reliable and readable in the sunlight of a cockpit are currently high cost. An additional issue is the ability of the display to simultaneously support numerous applications from simple text messages to detailed weather graphics, other aircraft positions, navigation information and terrain. Generally, each application has developed its own display approach. The pilot needs fused applications and potentially symbolic representations in order to quickly understand and react to information. The approaches used for solving the display issues will drive requirements for the AAIS, including the network and server components.

Types of information for the pilot display are:

- Flight symbology graphics showing boundaries based on weather such as in Instrument Flight Rules (IFR), Instrumented Meteorological Rules (IMRs), or Marginal Visual Flight Rules (MVFRs)
- Heads-up display symbology with uplinked taxi information
- Fused display information about terrain, tower obstacles, and proximate aircraft
- Hazardous weather contours such as wind shear in terminal area, and icing, hail, turbulence and lightning areas
- Taxi instructions including active runways and airport layout

Display alternatives include the use of Liquid Crystal Diode (LCD) displays , synthesized voice and direct projection to the eye. LCDs may be useful for small aircraft with cost or size limitations. Military pilots have used helmet-mounted projection techniques to provide data to the pilot without obscuring the view. Commercial applications are also being developed for personal computer users. A projected view approach would assist GA pilots since it would not require heads-down and it should also be easier to fit into small aircraft.

Research is recommended to investigate display technologies for use in aircraft, identify the most suitable means of presenting information to the pilot and to address human factors issues associated with the presentation of information.

2.1.1.4 Intelligent Router

The ATN concept includes an aircraft router function that will allow the aircraft to communicate with a number of different ground applications such as CPDLC, ADS, and AOC. Research will be needed to define the router function and determine how to implement it with sufficient redundancy, security, and priority for the additional services such as FIS and TIS.

General specifications and the internal architecture for such a router should, if possible, correlate with high-speed routers supporting terrestrial internetworking (single board computer, configurable and modular). The router should also be able to manage multiple air/ground links employing policy-based routing to optimize the link selection for each message or condition such as out of range or radio failures. Furthermore, the router must handle all data in and out of the airplane, including telephony, video, audio, digitized voice, text and graphics.

One approach is a multiprotocol aircraft router, applicable to both the cockpit and the cabin that would enhance reliability and lower the cost. Protocols supported include legacy protocols such as Aircraft Communications Addressing and Reporting System (ACARS), the transition protocol of ACARS over Aviation VHF Link Communication (AVLC), commercial protocols such as TCP/IP, and ATN protocols such as TP4/CLNP.

There are three possible implementations to consider: 1) The protocols could exist in the same router. Current ATN implementations are using this approach for the "dual stack" of ATN and ACARS legacy protocols. 2) Multiple routers could be used, each dedicated to a separate protocol or stack but able to be reconfigured in the event of failure. 3) Gateway or conversion approaches could be used to change legacy protocols into ATN or future commercial protocols either in the ground network or within the aircraft system. Although the dual stack approach is being developed today, it may not offer the configuration flexibility and speed necessary for the expected traffic loads (see Task 5).

2.1.2 VHF Link Improvements

Certain measures should be taken to improve the VHF infrastructure proposed by the NAS 4.0 Architecture. These improvements include a new antenna design, new modulation and compression techniques, and improvement to components used for voice transmission.

2.1.2.1 Directional VHF Antenna

Multiple VHF links are expected for future aircraft including combinations of 25 kHz DSB-AM voice, 8.33 kHz DSB-AM voice, ACARS, VDL Mode 2, VDL Mode 3, and VDL Mode 4. Installing multiple systems on large aircraft is difficult but usually manageable. Installation of multiple systems on small aircraft is difficult due to the limited space available and the risk of interference between systems. Reducing interference typically requires frequency separation as well as physical separation. Frequency separation reduces the spectrum available for use.

VHF aircraft antennas are currently omni-directional, which are low-cost and allow simple installation. The power gain of directional antennas is not needed for the communication ranges (200 nm maximum) of aircraft. However, directional antennas provide increased protection from unwanted signals outside the pointing angle of the antenna. A directional VHF antenna may be useful for the VHF data link problem if it is low cost and reliable. Electrically steerable antennas have been designed for other bands and services and the technology may be transferable to aviation. A combination of antennas or a switchable configuration of the antenna from omni to directional could allow initial operation in an omni mode to find a station, then switch to the directional mode once the station is located.

2.1.2.2 Modulation

The D8PSK modulation scheme selected by ICAO for VDL Mode 2 and VDL Mode 3 was based on the existing 25 kHz spacing in the VHF band, relatively short messages, and two-way communications. Modulation schemes considered were Differential Eight-Phase Shift Keying (D8PSK), Eight-Level Frequency Modulation (8LFM), 4-ary Quadrature Amplitude Modulation (4QAM), and 16-ary QAM (16QAM). ICAO working paper, AMCP/WG-C/5 summarized the modulation analysis as follows:

- 4QAM has insufficient throughput and was primarily considered to improve range and fading performance.

- 16QAM is the most complex scheme and is significantly more costly than the others. It has less certain performance at longer ranges and under fading conditions.
- 8LFM has a nonlinear transmitter that can provide more RF power on the channel and provides more margin than D8PSK.
- D8PSK has greatly superior adjacent channel interference performance for digital modulation against digital modulation (Mode 2, Mode 3, or combinations)
- D8PSK provides a channel data rate of 31.5 kb/s with a baud rate of 10.5 kbaud and three bits per symbol.

The detailed discussion in the ICAO paper indicated that 16QAM could yield a throughput of 37.8 kb/s for longer (1024 octet) messages based on a 25 kHz bandwidth. FIS and other services using large message sizes could benefit from the greater throughput. However, the Adjacent Channel Interference (ACI) would be a significant factor if a weather service is proposed in the aeronautical VHF band.

If the original assumptions and constraints for FIS-B are changed, a more efficient modulation scheme may be possible and more appropriate. Possible changes include: 1) Increase the 25 kHz bandwidth, 2) Assign FIS to another band, 3) Revise the modulation analysis based on broadcast only transmission.

2.1.2.3 Virtual Network

Current frequency allocation practices are based on analog voice radio techniques and assign a single frequency to each ATC control sector on a non-interference basis. With the advent of digital communications such as VDL Mode 3, more efficient frequency usage is possible. Figure 2.1-3 Frequency Usage, illustrates the transition from existing analog assignments to future VDL Mode 3 assignments. VDL Mode 3 will provide more virtual channels and enable growth or additional services.

A new national frequency assignment strategy that maximizes the capability of Mode 3 should be developed. The application of virtual network approaches used in systems such as cellular telephone, which maintains the connection as the vehicle moves through the various frequency service areas should be considered. The virtual network approach could be applied to shared services such as FIS but can not be applied to controller services such as CPDLC without changing the one frequency/one sector/one controller criteria.

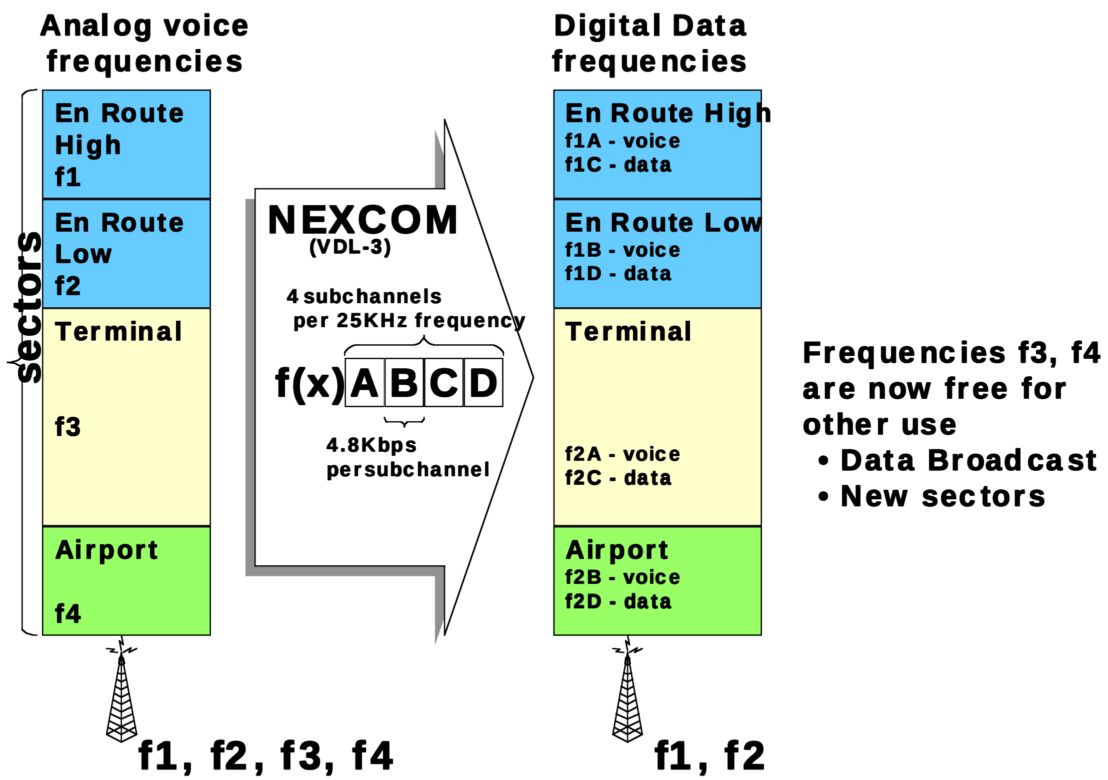

Figure 2.1-3. Frequency Usage - Analog to VDL-3

2.1.2.4 Compression

Compression techniques were envisioned for some of the air-ground information transmission in this study. Highly critical information such as navigation, surveillance, and air traffic control commands can not typically be compressed to a significant degree. Graphic products such as TIS and FIS can be compressed, perhaps as high as 100:1 depending on the resolution needed for the product. Compression of the information is desirable in order to reduce the bandwidth required.

A related approach to saving bandwidth is to minimize data at the application layer by text or symbol compression; example being the use of predefined messages in CPDLC. Instead of sending the text characters, each message is represented by a number with associated fields for variable information such as altitude, speed, and heading. Since the set of ATC messages has been refined over the years, a standardized set can be used to represent the most common messages. Free text formats are available for unusual situations. Weather products may also lend themselves to reduction at the application layer. It may not be necessary to send a large weather graphic to the aircraft - a symbolic representation may be sufficient. Optimizing applications has significant benefits to the data link including reducing the bandwidth requirement and allowing checksum and reasonableness checks (certain values should never occur for a given field).

Research and analysis is needed to determine how much is acceptable, which information or products can be compressed, and how the pilot will cope with missing or incomplete information that may be lost by combinations of compression, interference, and/or outages.

2.1.2.5 Voice Synthesis

Pilots of Class 3 aircraft are familiar with data link because they have been using it for a number of years. In two-pilot cockpits, data link messages are frequently handled by the non-flying pilot to avoid "heads-down" by the primary pilot. GA (Class 1 aircraft) are typically single pilot and they have expressed concern that it will be difficult for a pilot to use data link because of the heads-down issue. A voice synthesis capability on the aircraft would allow pilots to listen to their data messages rather than having to read them. Voice synthesis has been used for Digital-ATIS messages and is well established outside of aeronautical communications. It could be applied to CPDLC messages and any current text message including current weather text messages.

Although voice synthesis is not a new technology, applying it to the cockpit will require additional effort. A large number of voice synthesis products exist and all products may not be acceptable for conversion of ATC and weather information. Research should be conducted to apply voice synthesis technology to the cockpit and to develop acceptability standards to support testing and certification of products both for the aircraft and for associated ground based systems.

2.1.3 SATCOM

The use of Ka-band satellite is suggested for broadcast FIS and TIS data distribution. This section describes the required research associated with the use of Ka-band Satellite including multi-mode radio with Ka-band interface, modulation techniques, mobile standards, receiver improvements, and antenna improvements.

2.1.3.1 Multi-mode Radio with Ka-band Interface

Current air/ground radio designs are based on multi-mode radios that can provide AM, VDL Mode 2 and VDL Mode 3 modulations. The multi-mode approach lowers the number of total radios required on the aircraft, eases the transition problems of establishing the new modulations, and enables aircraft to operate in numerous geographic regions without changing equipage. A Ka-band interface to the existing multi-mode radios would be desirable to permit satellite communication to be integrated with other radio operations.

2.1.3.2 Modulation Techniques

Communications links at the frequencies in the Ka-band are degraded by rain and blocked by obstacles in the line-of-sight. Attenuation caused by oxygen and water vapor in the Ka-band is in the neighborhood of 0.1 dB/km to 0.2 dB/km. A study in 1993 by the NASA ACTS Program shows that typical rain attenuation in the Ka-band is in the neighborhood of 7 dB. To mitigate this severe attenuation during rain, several approaches such as alternate path to avoid rain and coding have been proposed. Viterbi coding can improve the satellite link margin; using PSK modulation with the rate 1/3 and 1/2 Viterbi decoders (Clark, G. and Cain, J., "Error-Correction Coding for Digital Communications," Plenum, 1988) and an error rate of 10-5 with constraint length of 7, one can expect a processing gain of 7 dB. Since the data were taken using fixed stations, further analysis and research is recommended to establish the effectiveness in flight situations.

Higher efficiency modulation techniques of 8-PSK and QAM appear appropriate to Ka-band satellite applications. To optimize satellite power and bandwidth utilization, 8-PSK or 16-QAM modulation together with a Turbo code can be used. As compared to QPSK or BPSK (the two most used digital modulations in satellite communications) 8-PSK uses two-thirds of the bandwidth required by QPSK and only one-third of the bandwidth required by BPSK. The use of Turbo codes is a new forward error correction (FEC) technology that also offers significant improvement over common conventional convolutional FEC techniques. It is recommended that their performance be evaluated based on the proposed aeronautical data and high to low speed platforms.

2.1.3.3 Mobile Standards

We have recommended the Ka-band primarily because of its relative availability of radio spectrum. Lower bands are technically feasible but are already crowded with existing users and applications. Use of satellite communications links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. In addition, satellite usage for Ka-band requires a number of political and economic initiatives. Satellite spectrum is internationally allocated. If a dedicated aeronautical band is required, the frequency will have to be proposed and accepted in a process that traditionally requires many years. If the proposed "industry partnership" approach is followed, a near term satellite allocation could be used. This approach would not provide the frequency protection of existing aeronautical bands and additional consideration should be given to priority schemes, procedures to mitigate failure or blockage of signals, and redundancy.

As previously mentioned, the Ka-band is attenuated by rain, water vapor and oxygen at certain frequencies. Coding methods provide additional gain that can offset rain attenuation. Satellite diversity may also be applicable if the space segment includes multiple satellites. LEO, MEO and HEO constellations and combination of LEO/MEO/GEO/HEO constellations could provide diversity to the aircraft. GEO constellations might provide diversity if multiple satellites are in view since each satellite signal would pass through different amounts of atmospheric attenuation.

It is recommended that the potential of LEO, MEO, HEO and GEO constellations to provide communications diversity to aircraft in order to overcome rain attenuation effects be studied.

2.1.3.4 Receiver Improvements

Existing Ka-band receivers are made for high bandwidth, fixed or broadcast services. None are currently intended for mobile service. An aircraft receiver should be lightweight, low cost, and must work with the antenna, and modulation scheme to provide operation throughout the dynamic maneuvers of the aircraft. A receive-only radio can be less expensive than a radio with transmitting capability. Achieving low cost for the user may require a tradeoff in performance between the bandwidth and modulation scheme. Modulation schemes with lower throughput may be used to increase range, decrease fading, reduce interference, lower antenna cost, or to adapt to dynamic performance. Research should be conducted to develop an effective design for a low cost aircraft receiver that addresses all of the mobile factors.

2.1.3.5 Ka-band Antenna Improvements

The requisite future aircraft antenna must be a high-performance subsystem that maximizes gain while minimizing system temperature. Such an antenna must be capable of electronically tracking the satellite with a pointing error of less than 0.25°, while permitting a small profile of less than 20 centimeters (8 inches) to minimize its impact on the airplane aerodynamics. The required aircraft antenna system must contain a two-way (receiving and transmitting) antenna, low-noise amplifier, down/up converter, high-power amplifier, diplexer, and associated RF cables and aircraft wiring.

The antenna system must fit into a radome installed on the aircraft fuselage no higher than 15 centimeters (6 inches). The antenna system figure of merit gain to system voice temperature (G/T) must be better than 10 dB/K. The frequencies that allow such high performance from small antennas are in the Ku band and above (Ku, Ka, Q, and V bands). The antenna would require high directivity supported by an electronic steering system (based on aircraft position and attitude and RF reception maxima) that orients the antenna toward the satellite to optimize reception. The antenna system half power beam-width must be below 5 degrees in both directions to minimize interference and comply with Federal Communications Commission (FCC) regulations. Research is required to develop antennas that meet these characteristics for all classes of aircraft.

2.1.4 TIS Interface

Pilots are currently limited in their ability to perceive other aircraft. Even in clear weather, aircraft speeds limit the time available for pilots to detect and recognize an aircraft and determining relative speed, direction and altitude is difficult. Aircraft frequently encounter each other without prior warning in uncontrolled airspace and weather conditions and darkness can increase the difficulty. The TIS service will provide traffic information processed on the ground to the aircraft for display to the pilot. A graphical format on a multi-function display is the most common display approach although other methods have been postulated.

The proposed Ka-band data link appears to be an appropriate medium for distributing the TIS data to all users of the NAS. Known performance requirements are within the ability of a satellite. TIS data could be combined in the uplink feed with FIS and NWIS data.

It is recommended that standards, protocols, and some performance characteristics be defined for a TIS communications interface and satellite distribution approach.

2.2 Cross Cutting Technology Gaps

In Task 10, certain gaps have been identified that affect the communication system architecture but are independent of communication media or apply to more than one service. Because these gaps cut across multiple services, they are discussed separately below.

2.2.1 Communications Interface to NAS-Wide Information System (NWIS)

The NAS-wide information system is not yet defined but in all probability can be thought of as a collection of information sources that — logically combined — form the information base of static and dynamic data of the NAS (see Figure 2.2-1). This is the data that feeds the FIS and TIS technical concepts that are a part of our CSA. The challenge faced by the CSA in interfacing with a distributed information source such as the NWIS is one of access to all the necessary data required.

From a CSA point of view, a NWIS logical mapping of data locations will be required in order to be able to collect and disseminate broadcast data. This could be similar to the domain name server approach used on the Internet today.

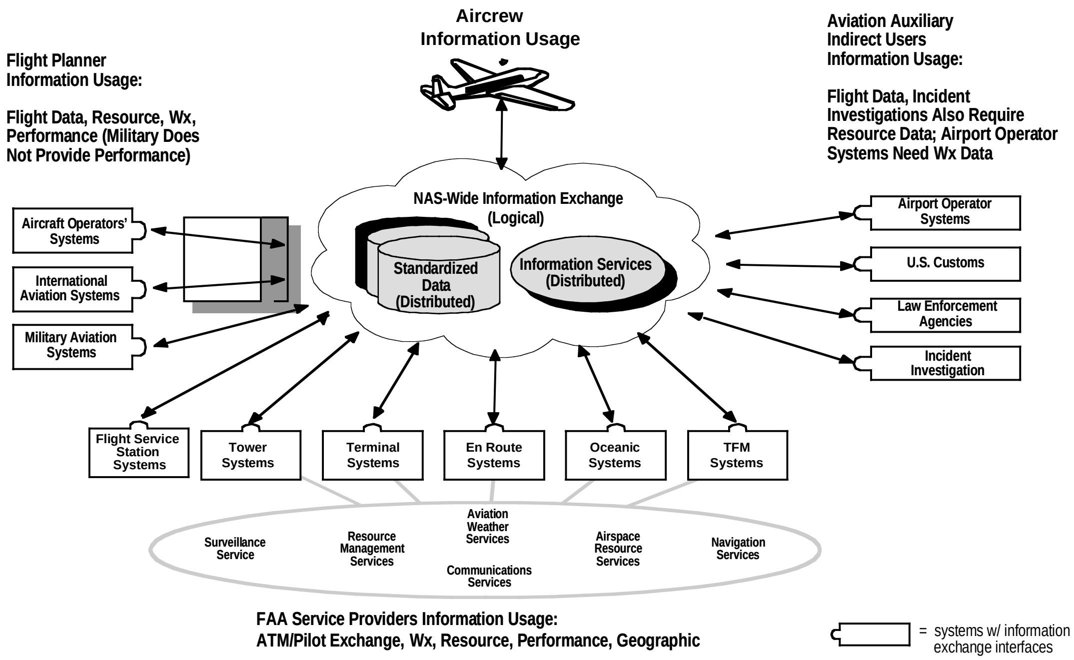

Figure 2.2-1. NAS-Wide Information System[1]

The wide variety of data exchanged via the NWIS will need a consistent set of standards such as data field formats, time stamping, integrity checking, updating, security classification, and compression categorization. The data standards will impact the communications requirements of latency, capacity, integrity, availability and information security.

Research is recommended to define the implementation of the NWIS and how it interfaces with the elements of the communications system recommended by this task order.

2.2.2 Information Security

Information security is considered as a cross-cutting system gap.

ICAO is studying aspects of security and has reached agreement on the following approach for the ATN (See Figure 2.2-2 ATN Security Approaches). ATN security services are provided at the application layer for both the air-ground data link and ground-ground ATC Message Handling Services. This provides integrity protection of ATN message contents. Security services are required at the network level for Inter-domain (between countries) IDRP messages that are transmitted between routers on each side of the domain boundary. Security services are optional (i.e. a local issue) at the network level for Intra-domain (within a country) and IS-IS protocol messages. Security services are optional (i.e. a local issue) at the network level for ES-IS protocol message connections.

[1] NAS Architecture Version 4.0, Figure 19-2.

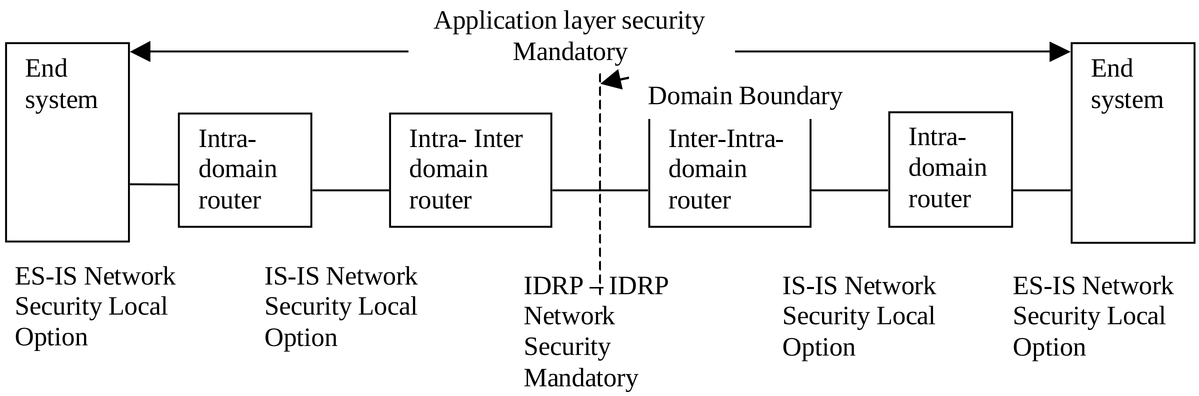

Figure 2.2-2. ATN Security Approaches

We recommend that NASA actively participate with ICAO and the industry to establish ATN security requirements and standards in the areas discussed below.

2.2.2.1 Authentication

A key concern for air traffic control applications such as CPDLC is the assurance that control messages are from a legitimate source (i.e. - controllers). In information security terms, this function is termed authentication and is based on secure means of identifying the sender of a message. ICAO is defining an authentication approach for ATN applications. Authentication adds processing delay and overhead to messages that will need to be considered in the traffic loading and analysis of future links. Authentication for non-ATN systems will require definition if commercial technologies are applied and proposed for air traffic services.

2.2.2.2 Data validation

In this context, data validation is the ability of the user to receive data that is correct and uncorrupted. Data validation would prevent the changing of data by a third party. This is distinct from the integrity of the data which refers to the error correction and message assurance capabilities of the protocols. The reliance on a wide variety of data from NWIS and other sources increases the need for a data validation approach, which is not currently being studied.

2.2.2.3 Deliberate Interference/Sabotage

A number of means exist to cause interference to the communications systems and to deliberately sabotage them. For all radio frequency (RF) links, deliberate and accidental interference is possible. The aeronautical frequency bands such as VHF are allocated on a non-interference or protected basis. If someone causes interference, the damage is usually localized to a single station and frequency and actions are taken to eliminate the interference. Commercial systems outside the aeronautical protected bands such as the proposed Ka-band, may be allocated on a shared basis which increases the potential for accidental interference. As the aircraft fleet is increasingly dependent on the data provided by TIS, FIS and other ATS applications, interference could cause major traffic disruption.

Deliberate interference can be caused at both the RF link and on the ground network. Deliberate interference or jamming, is similar to the accidental interference described above but is more difficult to determine and resolve since the perpetrator must be forced to cease interference.

Ground networks are becoming more vulnerable to deliberate attack as widely used protocols such as Internet Protocol (IP) are used. IP is vulnerable to denial of service attacks.

The mixture of air traffic control and commercial technologies and services proposed for the 2007 time frame require a means to protect the communications links and data sources from deliberate and accidental attacks. Procedures to maintain safe air traffic operations in the event of service interruption are required.

For data links, security is needed at both the application layer and network layer. Firewall software developed for terrestrial networks may be applicable to airborne environments.

3 Acronyms

Term	*Meaning*
AAC	Airline Administrative Control
AATT	Advanced Air Transportation Technologies
AAIS	Advanced Aircraft Information System
AMSRS	Aeronautical Mobile Satellite (Route) Service
AOC	Airline Operational Control
ARINC	Aeronautical Radio Inc.
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
AWIN	Aviation Weather Information
BER	Bit Error Rate
COTS	Commercial Off-The-Shelf
EMC	Electromagnetic Capability
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FEC	Frame error check
FOQA	Flight Operational Quality Assurance
FMS	Flight Management System
FSS	Fixed Satellite Service
GA	General Aviation
GPS	Global Positioning System
G/T	Gain to System Noise Temperature Ratio
HF	High Frequency
IFE	In-Flight Entertainment
IFR	Instrument Flight Rules
IP	Internet Protocol
LAN	Local Area Network
MFD	Multifunctional Display
NAS	National Airspace System
PSK	Phase Shift Keying
QAM	Quadrature Modulation
QoS	Quality of Service
RF	Radio Frequency
SAIC	Science Applications International Corporation

SATCOM	Satellite Communications
SOW	Statement of Work
SSR	Secondary Surveillance Radar
VHF	Very High Frequency
WAN	Wide Area Network